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HYDROGEOLOGICAL ASSESSMENT OF CENTENNIAL PARK WASTE DISPOSAL SITE, TRENTON (No. 360201)

NOVEMBER 1988

JUNE 1989

Environment Ontario

Jim Bradley
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(No. 360201)

NOVEMBER 1988

Report prepared for:
Waste Site Evaluation Unit
Waste Management Branch

Report prepared by:
Water and Earth Science Associates Limited

JUNE 1989

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1.0 INTRODUCTION

The Province of Ontario currently generates an estimated 1.5 million tonnes of solid domestic and industrial waste per year. Due to the long list of health and environmental problems associated with waste disposal sites, the Ministry of the Environment (MOE) has made a concerted effort over the last decade to upgrade waste disposal facilities into viable sanitary landfill sites. Sanitary landfills are now the most common disposal method being utilized in Ontario.

Many landfills in Ontario have been closed within the last 10 to 15 years in which there is sparse information on waste disposal practices, the type of waste that was disposed of and the closure procedures utilized at the sites. The MOE is presently implementing a program to investigate all closed and active waste disposal sites in the Province. The aim of this program is to ensure that all relevant information regarding the sites' existing or potential impact on either humans or the environment is available. Once this information is provided, remedial options can be investigated and implemented where necessary.

Phase III of the MOE's program of waste disposal facility evaluation involves the investigation and monitoring of hydrogeology as well as surface and groundwater contamination potential at selected sites. The investigation reported below deals with the closed Centennial landfill site in the City of Trenton. The objectives of the study as outlined in the Request for Proposal are as follows:

1) to determine the leachate characteristics with attention to the possibility that an unidentified industrial liquid waste may have been disposed of at the site

2) to define any existing or potential impacts on surface water including the Bay of Quinte

3) to define the extent of a landfill gas hazard

4) to define the site's present physical condition, and

5) to develop recommendations that will lead to site improvements with respect to site monitoring and remedial action.

2.0 BACKGROUND

The Centennial Park landfill site is located on the shores of the Bay of Quinte, a short distance east of the entrance to the Trent River. The site is bounded by residential property to the north and east while the Bay of Quinte borders

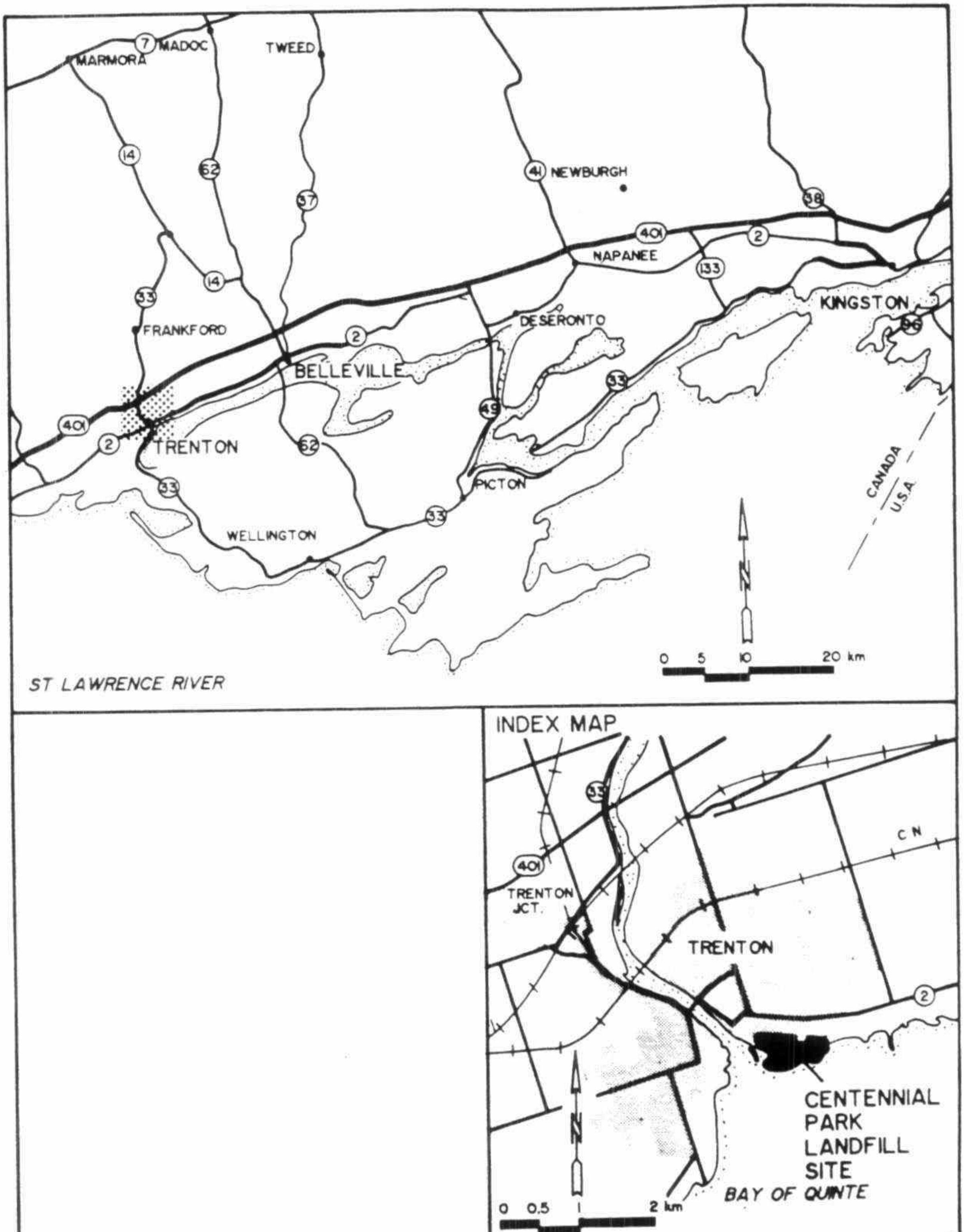

FIGURE 1

LOCATION MAP

CENTENNIAL PARK LANDFILL SITE

TRENTON, ONTARIO.

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the site to the south and west (Figure 1). Little information is available on the site history and no records of landfill development or operation were kept. The following information is based on interviews with personnel from the City of Trenton, Public Works and Parks and Recreation (notably Mr. Arie Hoorweg, Commissioner of Public Works, who has been in charge of site operations and restoration).

The landfill was constructed on a marshy shoreline area of the Bay. Gilmor Lumber operated a sawmill on the site from the beginning of the century and as a result the northwest area was covered by sawdust refuse before domestic landfilling began.

It is believed that landfill practices began in 1955 and continued until May, 1971. Site operations consisted of the construction of artificial berms of broken limestone and fine grained fill that were built in small patches onto the Bay of Quinte. The resulting lagoons were pumped out and sediment was also occasionally excavated to bedrock. The lagoons were filled with refuse and capped with pit run gravel. Some restoration was carried out as the site was filled. The site was generally filled from west to east. Figure 2 illustrates the limit of landfilling at the site.

At the time of closure (May, 1971), the site covered a 14 ha area and served a population of approximately 14,000. Thirty to thirty-five tons/day of waste entered the site. The waste was estimated to consist of 58% domestic waste, 30% commercial waste, 10% industrial waste and 2% liquid industrial waste. An inventory of industrial plants that may have used the site has been compiled (Appendix A).

The site was closed in 1971 for the following reasons:

- its capacity was nearly reached
- the berm/lagoon operation method was not favoured by the MOE
- berm integrity was questioned
- gas evolution was observed in the Bay of Quinte adjacent to the berms and low dissolved oxygen levels were measured in the lake along the berms
- the Ontario Water Resources Commission was concerned that landfill-related pollution was interfering with adequate dilution of sewage effluent

A small sewage treatment plant was located next to the landfill on clean fill. Approximately three years after the site was closed, a large, modern treatment plant was constructed adjacent to the site on land which was reclaimed from the Bay of Quinte. Trenches for sewer mains leading to the plant were all clay lined.

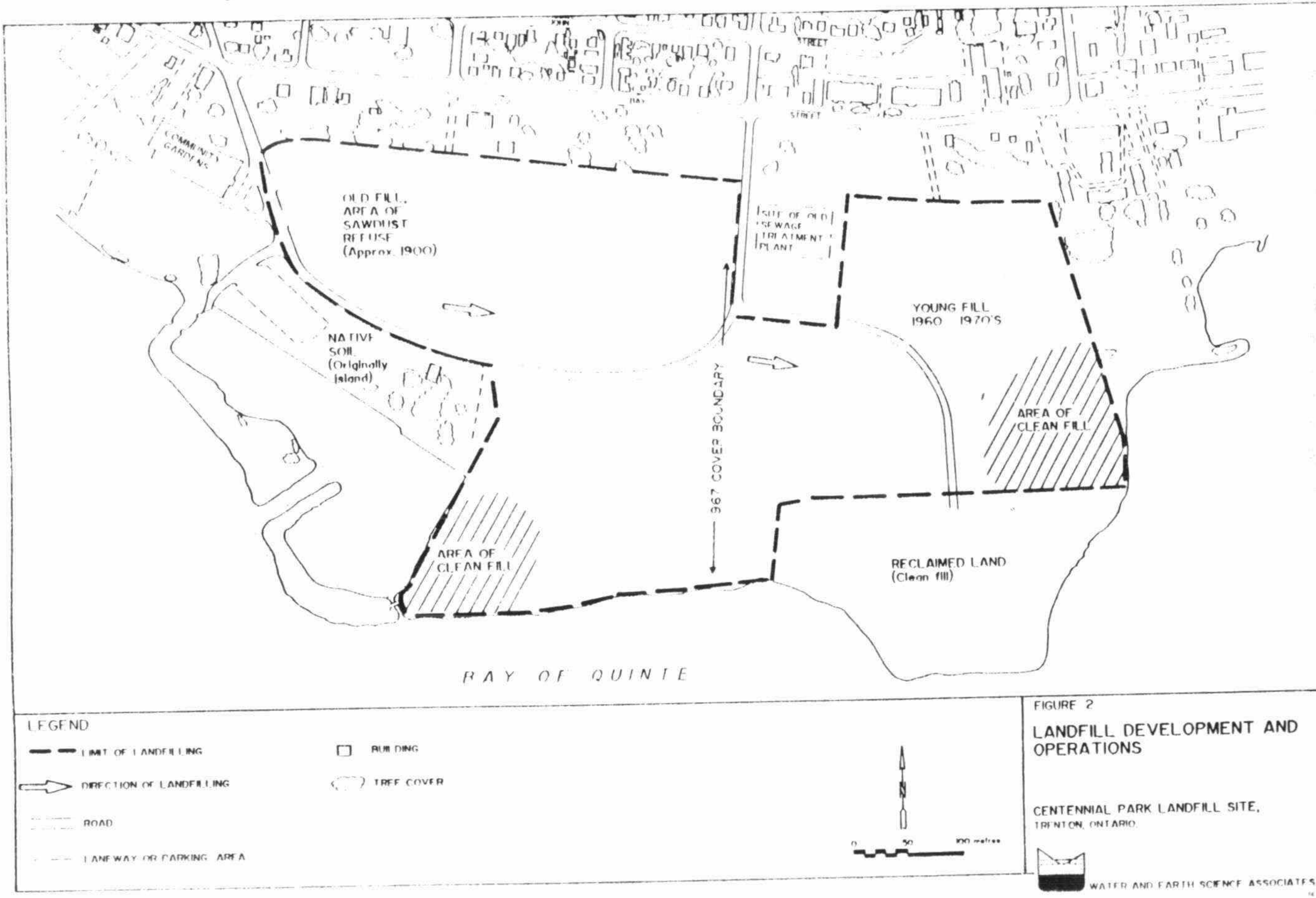


FIGURE 2

LANDFILL DEVELOPMENT AND OPERATIONS

CENTENNIAL PARK LANDFILL SITE,
TRENTON, ONTARIO.

Concern over Bay of Quinte water quality degradation due to leachate emanating from the site prompted MOE officials to begin sampling the Bay of Quinte water around the landfill in 1979. The results of these samplings in October 1979 and March, 1981 are listed in Appendix B). All samples were within the drinking water objectives for all the tested parameters with the exception of slightly elevated TKN (total Kjeldahl nitrogen) values.

After filling was completed on the west half of the landfill, it was capped and turned into parkland. The area was landscaped and lawn bowling, soccer, tennis, baseball and general recreation facilities were constructed. The park was officially opened as Centennial Park in 1967. Filling of the remainder of the site was continued until 1971.

An outdoor amphitheatre and public washroom were constructed at the park in early 1971 on part of the old landfill site. During the construction refuse was encountered in some test holes but the overburden consisted mostly of gravel beneath 1.0 to 1.2 m (3-4 ft) of stoney, silty sand. As a precaution to the possible methane gas buildup in the structure, the overburden beneath the buildings was capped by a clay liner and oxygen deficiency meters and methane gas detectors were used during the construction phase of the complex. Gas ventilation holes were also incorporated into the building's structure. No methane gas problems have since been reported to or by the City of Trenton. Figure 3 illustrates the present landuses on the closed landfill.

3.0 METHODS OF ANALYSIS

The following section describes the method of study followed in the investigation.

3.1 Borehole Drilling

The location of on-site buried services and utilities were established on the morning of April 25, 1988 at a joint site meeting. A total of eight boreholes were drilled on the site from April 25 to 26, 1988 by All-Terrain Drilling Ltd. The tire mounted CME 75 drill rig used split spoon sampling, and standard penetration testing to provide information for borehole logging which was carried out by senior and intermediate WESA staff. Samples were collected, sealed, labelled and stored.

3.2 Health and Safety

Since there were no accurate records of the substances disposed of in the landfill, care was taken to ensure that workers were not exposed to hazardous contamination and to prevent them from inadvertently carrying toxic substances off the site on clothing or equipment.

A photo-ionization detector (PID) and combustible gas meter were used on-site to monitor air quality in the working area around the drill and off gases from the split spoon samples and auger cuttings and inside the hollow stem augers. Disposable Tyvek coveralls and Tru-touch inner and heavy outer plastic gloves were worn while drilling and removed when the workers left the site.

Air purifying respirators and protective goggles were available to all personnel if the PID or combustible gas meter detected the presence of hydrocarbons or combustible gases in the air. A powered air rescue pack was also available in case an emergency situations arose. In fact, gases were detected only once, at the third methane well (M3), where methane was measured at >1% by volume.

In the event that high levels of contamination were encountered, workers were prepared to follow the MOE "Occupational Health Protocol" (October 23, 1977).

Hard hats and steel toe, steel shank safety boots were worn at all times during the drilling investigations.

3.3 Borehole Instrumentation

Four boreholes were instrumented as piezometers with two multilevels) and the remaining four as gas probes.

Piezometers were constructed of 31.8 mm (1 1/4 inch) schedule 40 PVC pipe, connected with pressfit PVC joints and finished with 10 slot PVC screen. No glue or solvents were used. Our experience at the Gloucester landfill site (WESA, 1986, Devlin, 1987) indicates that PVC and polyethylene piezometers can be employed for reconnaissance organic testing, provided that stringent sampling protocols are used. The two multilevel piezometer installations were labelled as follows: the deepest piezometers were labelled with a suffix of 1 (ie. P3-1) and the more shallow piezometers were labelled as P3-2. A gas probe was also installed above the groundwater table in each of the piezometer holes, as described below.

Methane gas probes were constructed of 1/2" polyethylene tubing with slotted polyethylene tips wrapped with No. 210 nytex screen. Up to three tips were installed in each installation at 30 cm vertical intervals to ensure that the gas was sampled immediately above the groundwater table.

All installations were finished at grade and protected with locking caps in order to minimize interference with the park activities.

Locations of the installations are shown in Figure 3. Borehole logs showing details of each installation are found in Appendix C.

3.4 Physical Hydrogeology Monitoring

Physical hydrogeology monitoring was completed in order to target areas for geochemical sampling and to determine groundwater flow characteristics. Water levels were obtained in all piezometers, the tops of which were subsequently surveyed and tied into the elevation contours. This information, along with the drill logs, was tied to a relative datum in order to define the general three dimensional site hydrostratigraphy.

3.5 Geochemical Sampling and Field Monitoring

3.5.1 Groundwater Samples

Wells were developed by removing 5-6 pore volumes prior to sampling where possible. Difficulties were encountered during the developing in the shallow, low yield wells installed at Trenton (specifically P3 and P4). After removal of one pore volume, the well remained dry. In this case, sampling was done on the next, and in some cases, subsequent days in order to obtain sufficient sample volume. Due to these difficult sampling conditions, these wells had only a single pore volume removed during development.

Temperature, conductivity, pH and dissolved oxygen were measured in the field during sampling. Sample bottles were rinsed (except for phenol bottles which were pretreated), filled to the top, tightly capped without headspace and stored on ice at a temperature below 4° C. The following samples were taken:

TABLE 1: Details of Samples Taken

Parameter	Sample Volume	Bottle Type	Pretreatment/ Field Treatment
Metals	125 ml	Polyethylene	Filtered with a 0.45 micrometre millipore filter and acidified in the field
Anions, non-metal cations, COD	125 ml	Polyethylene	None
Phenols	250 ml	Amber Glass	Pretreated with $CuSO_4$, H_2O and H_3PO_4

Volatile Organics	100 ml	Amber Glass	Teflon septa lined caps
Extractable Organics	1000 ml	Amber Glass	Foil lined caps

Dedicated sampling tubes were used at each point sampled. Filtering equipment and tubing associated with the peristaltic pump used to extract the sample were cleaned with nitric acid, methanol and distilled water after each sampling point to prevent cross-contamination.

Inorganic Parameters

Groundwater samples were obtained from the six monitoring locations and were delivered to Dr. John Poland of Queen's University in Kingston for inorganic analysis. Dr. Poland's high quality laboratory was able to provide results on index parameters within 48 hours of sample delivery. These parameters were evaluated with field measurements and physical hydrogeological monitoring in order to choose monitoring points for organic analysis.

The following inorganic parameters were analysed:

TABLE 2: Details of Sample Parameters

Field Measurements	**Lab Analyses**	
Conductivity	Fe	NO_3-N
Temperature	Mn	NH_3-N
Dissolved Oxygen	COD	SO_4
pH	Alkalinity	Ca
	Phenols	Mg
	Cl	K
		Na

Organic Parameters

Samples for organic analyses were collected at all monitoring points. Based on the results of the phenols, iron, COD, chloride and field measured conductivity, temperature, pH and dissolved oxygen, organic samples were selected for actual analysis. It was more cost-effective to sample all locations for organics and subsequently select potential leachate samples than to only sample a few piezometers in a later site visit.

In keeping with the concerns of the MOE, samples from two selected monitoring points were delivered to Novalab of Lachine, Quebec, for analysis. Since the exact nature of any possible leachate was not known, a complete U.S. Environmental

Protection Agency (USEPA) priority pollutant scan for organics (USEPA Methods 624 and 625) was performed on each sample submitted.

3.5.2 Surface Water Samples

Two samples were obtained from the Bay of Quinte near the landfill site. Field measurements included temperature, conductivity, pH and Dissolved oxygen. The samples taken were obtained using the same protocol as that used with the groundwater samples, with the addition of a 1000 ml untreated BOD sample taken in an amber glass bottle. Surface water samples were taken at approximately 0.75 m depth, and less than 1 m offshore at locations shown on Figure 3. Analyses for COD were not performed on surface water samples.

3.5.3 Seepage Meter Samples

Seepage meters were not installed at Centennial Park Landfill for two reasons: large diameter boulders used for rip-rap along the Bay of Quinte near shore would have made installation extremely difficult, and the MOE indicated that this area was not a major concern (April 18, 1988).

3.5.4 Quality Assurance/Quality Control

Blanks and duplicates were employed in both organic and inorganic samples for quality assurance and quality control in the combined Picton and Trenton landfill studies. A field blank and field duplicate were taken for inorganic analysis. Trip blanks and laboratory blanks were used in the organic analyses. In addition, a field duplicate sample was submitted.

Results from the analyses of blank and duplicate samples are included in Appendix F.

All field equipment, including pH, conductivity, dissolved oxygen and the methane gas detectors, was calibrated under in-situ conditions to ensure the gathering of reliable, quality data.

3.6 Gas Monitoring

An Enmet GCIO combustible gas detector was used to monitor all installations for methane. The meter can be used to detect combustible gases up to 20% of the lower explosive limit (explosive conditions occur at 5% CH_4 gas by volume). Thus the highest concentration measurable by the Enmet meter, 20% of the explosive limit, is equivalent to 1% CH_4 gas by volume.

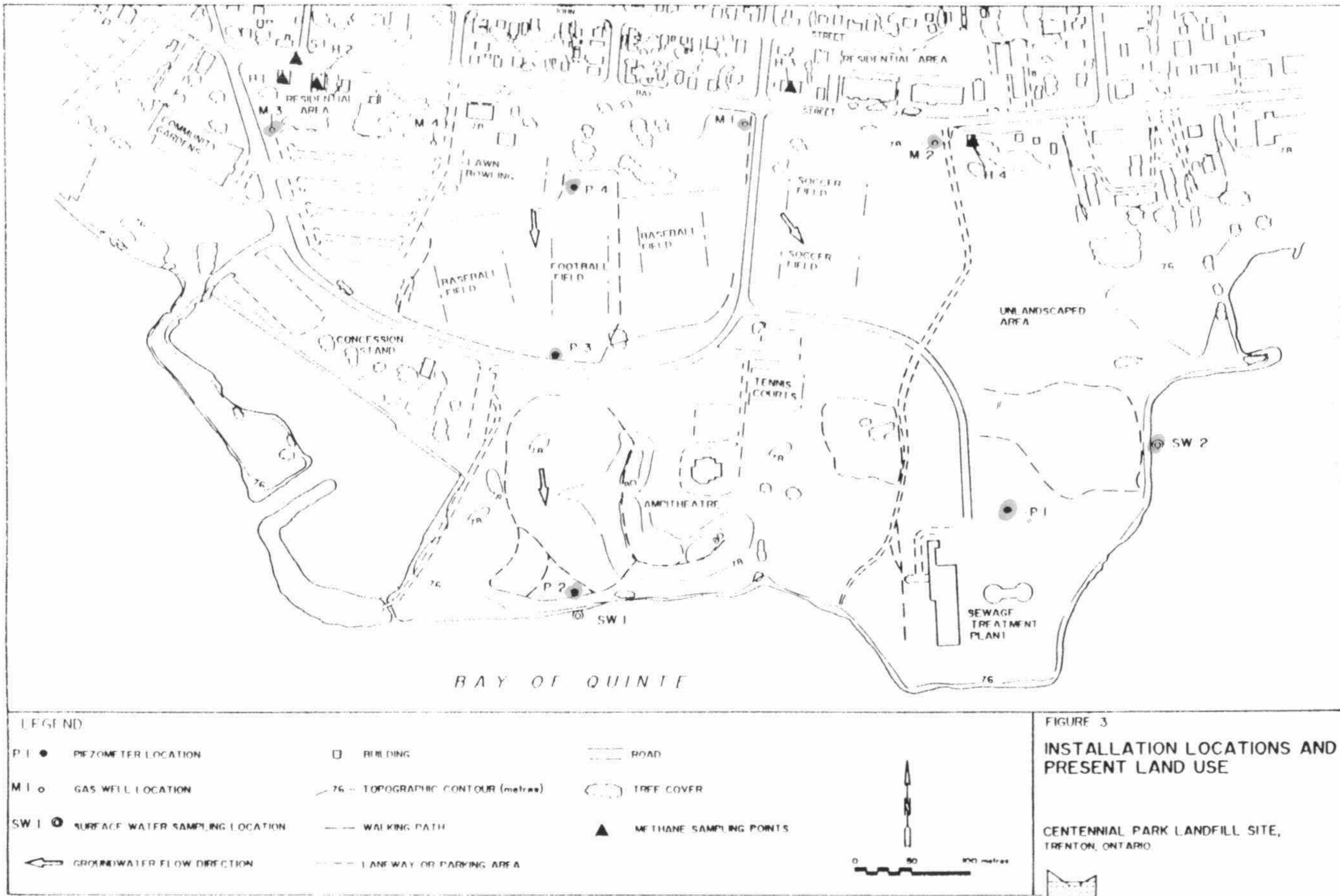


FIGURE 3

INSTALLATION LOCATIONS AND PRESENT LAND USE

CENTENNIAL PARK LANDFILL SITE,
TRENTON, ONTARIO

WATER AND EARTH SCIENCE ASSOCIATES

A tube was attached directly to the 1/2" polyethylene tubing of the gas probe. Gases were then pumped with a squeeze bulb directly from the well to the meters.

The Enmet meter was also used to monitor methane levels in a Bay Street storm sewer and in the basements of four homes judged to be the most susceptible to accumulation of methane. The monitoring locations are shown on Figure 3.

In addition, methane levels in the Centennial Park Amphitheatre and concession stand were monitored. The levels were measured in the spring, after the buildings had been closed for the winter months, and thus represent a 'worst case' scenario.

4.0 RESULTS

The results of the investigation are documented below, and will be discussed further in Section 5.0.

4.1 Physical Hydrology Monitoring Results

Table 3 shows the results from the location survey and from the water level monitoring.

Groundwater at any point flows in the direction of decreased hydraulic head. Hydraulic gradients, calculated as the change in hydraulic head divided by the distance between two points, are a measure of the driving force behind the groundwater flow. Groundwater velocity can be calculated as the product of the hydraulic gradient and hydraulic conductivity (a coefficient of material permeability to groundwater flow under saturated conditions.

Table 4A shows hydraulic gradients calculated vertically between two monitoring points in a single multi-level installation. Horizontal gradients between two different installations are calculated in Table 4B.

Vertical hydraulic gradients in the two multilevels indicated that the groundwater is flowing downward, or recharging the system. All horizontal hydraulic gradients indicate that the water is flowing towards the Bay of Quinte.

It is very difficult to assign a hydraulic conductivity value to a material as heterogeneous and anisotropic as landfilled waste. Based on the fact that small volumes of the refuse were recovered in split spoon samples and that any geologic material recovered in the waste during drilling was generally sandy with gravel or boulders, a relatively high hydraulic conductivity might be expected. A representative range of 10^{-3} to 10^{-5} m/s is assumed in this case. These values

TABLE 3: PHYSICAL HYDROLOGY MONITORING RESULTS
CENTENNIAL PARK, TRENTON

		P1-1	P2-1	P3-1	P3-2	P4-1	P4-2
A.	SURFACE ELEVATION (m A.S.L.)	77.88	76.50	76.75	76.75	77.30	77.30
B.	INSTALLATION DEPTH (m)	4.27	3.35	3.05	2.13	2.59	1.83
C.	ELEVATION OF SCREEN BOTTOM (A-B, m A.S.L.)	73.61	73.15	73.70	74.62	74.71	75.47
D.	STATIC WATER LEVEL (m BELOW GROUND)	2.17	1.45	0.93	0.88	0.89	0.87
E.	PRESSURE HEAD (B-D, m A.S.L.)	2.10	1.90	2.12	1.25	1.70	0.96
F.	HYDRAULIC HEAD (C+E, m)	75.71	75.05	75.82	75.87	76.41	76.43
G.	BEDROCK ELEVATION (m A.S.L.)	73.61	73.15	73.70	---	74.71	---

TABLE 4A: VERTICAL HYDRAULIC GRADIENTS IN MULTI-LEVEL INSTALLATIONS
CENTENNIAL PARK, TRENTON

FROM (1)	TO (2)	h(1) (m)	h(2) (m)	h(1)-h(2) (m)	d (m)	h(1)-h(2) / d
P3-1	P3-2	75.82	76.87	0.05	0.92	0.05 down
P4-1	P4-2	76.41	76.43	0.02	0.76	0.03 down

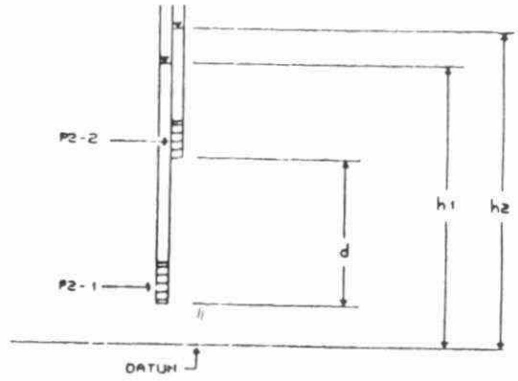
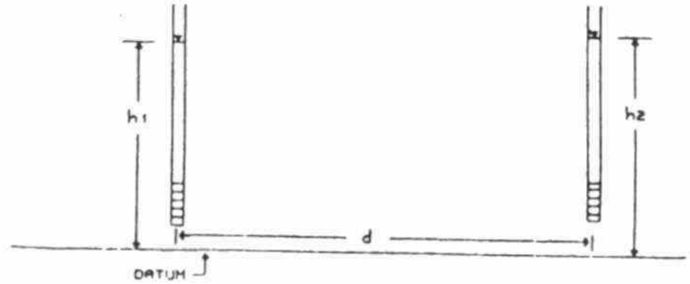


TABLE 4B: APPROXIMATE HORIZONTAL HYDRAULIC GRADIENTS ALONG THE
BEDROCK SURFACE

FROM (1)	TO (2)	h(1) (m)	h(2) (m)	h(1)-h(2) (m)	d (m)	h(1)-h(2) / d
P4-1	P3-1	76.41	75.82	0.59	166	0.0036 towards P3
P4-1	P2-1	76.41	75.05	1.36	375	0.0036 towards P2
P3-1	P2-1	75.82	75.05	0.77	219	0.0035 towards P2
P4-1	P1-1	76.41	75.71	0.70	501	0.0014 towards P1
P3-1	P1-1	75.82	75.71	0.11	445	0.0002 towards P1



correspond to a range of geologic materials from clean sand to silty sand (Freeze and Cherry, 1979). If these values are correct, they correspond to groundwater flow velocities from P4 towards P3 and P2 of 7 to 110 m/year. This suggests that infiltrated water may flush through the landfill relatively quickly before being discharged into the Bay of Quinte.

The level of water in the Bay of Quinte was measured at 74.98 m a.s.l. in May, 1988.

4.2 Inorganic Chemistry and Field Monitoring Results

Table 5 contains the results of field monitoring and inorganic chemical analysis.

Also included in Table 5 are the Ontario Drinking Water Objectives (revised by the MOE in 1984) and representative ranges for inorganic parameters in leachate from sanitary landfills (Freeze and Cherry, 1979).

4.3 Organic Chemistry Results

Results from the USEPA 624 volatile and the USEPA 625 extractable analyses are included in Table 6. The two sampling points (P1-1 and P2-1) were chosen for organic analysis on the basis of the following points:

i) generally the highest values for the four index inorganics parameters (measured within 48 hours of sample delivery) were found in these two points,

ii) iron was very high in P1-1 (52.5 ppm) and relatively high in P2-1 (11.6 ppm),

iii) the physical hydrology monitoring indicated these piezometers were downgradient of the major area of the landfill.

Concern caused by the lack of a trip blank for volatile organics in the May sampling prompted resampling of P1-2 in June, 1988. A trip blank was used on this occasion. Levels in the June sample were similar to those found in the two duplicate samples in May, 1988. The trip blank was clean with the exception of 1.7 ppb of chloroform (which was not found in any samples). Thus the May, 1988 samples are considered to be representative of the groundwater.

4.4 Gas Monitoring Results

The results of the gas monitoring are seen in Table 7.

TABLE 5: FIELD MONITORING AND INORGANIC CHEMISTRY RESULTS
CENTENNIAL LANDFILL, TRENTON

	GROUNDWATER SAMPLES						SURFACE WATER SAMPLES		ONT. DRINKING WATER OBJECTIVES (REVISED 1983)	RANGES IN LEACHATE FROM SANITARY LANDFILLS (FREEZE &CHERRY, 1979)	BLANK
	P1-1	P2-1	P3-1	P3-2	P4-1	P4-2	SW1	SW2			
FIELD MONITORING											
Conductivity (uS/cm)	1800	1170	800	600	800	1000	168	190	--	--	--
Temperature (oC)	11	10.2	10.2	12.0!	9	11	17.5	19	--	15	--
Dissolved Oxygen (ppm)	--	5.3	8.6+	--	4.6	6.1	9.0	12	--	--	--
pH	--	6.0	6.5	6.5!	6.55	6.45	8.0	7.0	--	4-8	--
INORGANIC CHEMISTRY RESULTS											
Fe (ppm)	52.5	11.6	9.0	1.8	30.2	4.9	<0.10	<0.10	0.3	1-1000	<0.10
Mn (ppm)	0.64	1.79	1.01	0.72	1.62	1.65	<0.05	<0.05	0.05	0.01-100	<0.05
COD (ppm) ++	82	65	77	56	74	320	<5	<5	--	1000-90,000	25
Alkalinity (ppm)	1290	1010	945	740	895	920	100	105	--	500-10,000	10
Phenols (ppb)	10.8	6.0	<1.0	1.4	4.0	6.6	4.4	4.2	2.0	--	<1.0
Chloride (ppm)	970	195	47	55	57	185	13	24	250	300-3000	<1
Nitrate-N (ppm)	<10	<1	<1	<1	<1	<1	<1	<1	10.0	0.1-10	<1
Sulphate (ppm)	<2	27	4	61	<2	42	12	16	500	10-1000	<2
Ammonia-N (ppm)	47	23	36	35	19	33	<0.10	<0.10	--	10-1000	<0.10
Calcium (ppm)	390	324	270	174	240	240	46	48	--	100-3000	<1.0
Magnesium (ppm)	42	43	43	26	26	26	3.6	3.9	--	100-1500	<1.0
Potassium (ppm)	32	10.9	36	27	28	28	1.2	1.5	--	200-1000	0.7
Sodium (ppm)	470	106	78	160	145	145	5.4	9.5	--	200-1200	2.1
Calculated Hardness	1147	986	851	541	707	706	130	136	--	660-13650	--

+ From bailed sample
! Poor, small volume sample
++ BOD was measured in surface water samples

TABLE 6: Organic Chemistry Results, Centennial Park Landfill, Trenton

	P1-1	P2-1	DWO*	MDL**
	VOLATILE PRIORITY POLLUTANTS (ug/l)			
Benzene	5.5	2.7	10	1
Chlorobenzene	32	2.4	60***	1
1,3-Dichlorobenzene	7.8	1.6	350	1
Ethylbenzene	1.6	1.4		1
Methylstyrene Isomers	-	-		1
Toluene	2.5	8	2000	2
M+P-Xylene	6.8	5.4		2
O-Xylene	2	2.4		1
Other Aromatic Compounds	170	11		1
	BASE/NEUTRAL PRIORITY POLLUTANTS (ug/L)			
BIS(2-Ethylexyl)Phthalate	1.5	1.2		1
DI-N-Buthyl Phthalate	6.7	3.5		1
1,4-Dichlorobenzene	3.7	-		1
Diethyl Phthalate	2.7	-		1
Fluorene	-	-		1
Napthalene	24	1.6		
	ACIDIC PRIORITY POLLUTANTS (ug/L)			
Phenol	1.6	-	0.002	1

Note: Only those compounds with detectable concentrations are included in the table. A complete listing of the EPA 625 and 624 compounds analyzed are included in Appendix E.

* Drinking Water Objective (WESA, 1988)

** Method Detection Limit

*** US EPA limit

TABLE 7: Methane Gas Monitoring Results, Centennial Park Landfill, Trenton

Gas Probe	%LEL	Equivalent $\%CH_4$ by volume*
P1	8	0.4
P2	15	0.75
P3	>20	>1
P4	>20	>1
M1	10^+	0.5
M2	3	0.15
M3	5	0.25
M4	9	0.45
H1	Nil	Nil
H2	Nil	Nil
H3	Nil	Nil
H4	Nil	Nil
S1 (Bay St. Storm Sewer	Nil	Nil

\+ >20% LEL measured during drilling
* The lower explosive limit is reached at 5% CH_4 by volume.

It should be noted that methane levels greater than 20% LEL were encountered in M3 during drilling.

Methane levels were measured at >20% LEL in the concession stand and at 5% LEL in the amphitheatre on May 11, 1988. After the concession stand was opened for the season, no methane was detected on June 5, 1988. The front and back doors were weft open to allow access to washroom facilities and allowed ventilation of the building at this time. Personnel from Parks and Recreation, City of Trenton were informed of these levels within 24 hours of their detection.

5.0 DISCUSSION

5.1 Physical Hydrogeology

A comparison of the locations and elevation of bedrock and ground surface at the piezometer installations (Figure 3) shows that both bedrock and ground surface and topography slope towards the Bay of Quinte. Flow regimes common in shallow sediments are commonly characterized by a flow along the slope of the bedrock towards the surface water.

Hydraulic head values and horizontal hydraulic gradients (Tables 3 and 4) confirm that the shallow groundwater is flowing towards the bay. Hydraulic heads were highest in P3 and P4 (which are furthest inland) and decrease in P1 and P2 toward the Bay of Quinte. In addition, vertical hydraulic

gradients in P3 and P4 (calculated as change in hydraulic head divided by change in distance) are both negative, indicating a downward gradient and that recharge is occurring.

5.2 Inorganic Chemistry and Field Monitoring

5.2.1 Groundwater

A brief comparison of the contents of Table 5 with the representative ranges of the inorganic constituents in leachate from sanitary landfills (Freeze & Cherry, 1979) indicates that the leachate at Centennial Park landfill has relatively low concentrations of most parameters.

Conductivity values measured in the field varied from 600 to 1800 us/cm, with the highest values recorded in P1 and P2.

Groundwater temperature ranged from 9 to 12^{o} C which is slightly higher than usually found in shallow groundwater. Groundwater temperature is normally equal to the Average Annual Temperature which equals 7.4^{o} C for the Trenton area. Chemical and biological activity in the landfill material may be generating some heat, causing the groundwater temperature to increase. Alternatively, the groundwater temperature may be equilibrating with the surface water temperature in the Bay of Quinte (measured at 17.5 to 19.0^{o} C).

Dissolved oxygen concentrations ranged from 5.3 to 8.6 ppm, indicating that relatively high oxygen concentrations are present in the leachate.

pH values measured in piezometers ranged from 6.0 to 6.55.

Iron and manganese levels ranged from 6 to 175 times the drinking water objective values of 0.3 and .05 mg/l respectively. Manganese ranged from 0.64 to 1.79 mg/l and iron from 1.8 to 52.5 mg/l. These metals are common constituents of landfill leachate.

The chemical oxygen demand measured at the site was less than 100 ppm in all points except for P4-2 which had a COD of 320 ppm. A comparison with the range considered representative for landfill leachates (1000-90,000 ppm) indicates that demands are low. This may indicate that most of the chemical activity associated with degradation of domestic wastes has already occurred. The high dissolved oxygen levels concur with this hypothesis since oxygen is often involved in and used up by degradation reactions.

Alkalinity values, expressed as equivalent $CaCO_3$, ranged from 740 ppm in P3-2 to 1290 ppm in P1-1. The levels are quite high, and also appear to be related to the calculated hardness of the water, suggesting alkalinity may be related to the limestone bedrock. Dissolved carbon dioxide constituents are the principal sources of alkalinity in most waters. Other non-carbonate contributors to alkalinity include hydroxide, silicate, borate, and organic ligands (especially acetate and proprionate).

Phenol concentrations are elevated in the landfill leachate, ranging from below detection limits (P3-1) to 10.8 ppb (P1-1), which is slightly more than five times the drinking water objective. Phenols can occur naturally in swamp or marsh areas like the one that originally existed at Centennial Park. They may also be landfill related and are most commonly associated with hydrocarbons or petroleum distillate disposal.

Chloride levels were above the drinking water objective in only one location (970 mg/l in P1-1). Sulphate levels were below the drinking water objective in all samples. These low levels also suggest that the groundwater is contaminated with relatively low strength leachate.

Detectable nitrate was not found in any of the sampling points. Ammonia is commonly associated with domestic waste and values ranging from 19 to 47 mg/l were recorded. These values correlate to the lower range of ammonia concentrations found in landfill leachates.

Calcium values, ranging from 174 to 350 mg/l, are moderately high, contributing to the hardness of the water. Magnesium and potassium occur at similar concentrations (10.9 to 43 mg/l) which are considerably lower than calcium levels and are well below the range of representative concentrations for landfill leachate listed in Table 5. Sodium levels (75 to 470 mg/l) are also below the representative range found in leachate, with the exception of a value of 470 mg/l measured in P1.

In summary, while common leachate constituents (ie. Fe, Mn, Cl, NH_3, Ca, Na) are elevated, they are all below or in the lower representative ranges for leachate in sanitary landfills included in Table 5. The relatively low strength of the leachate may be due to several factors:

1) the shallow depth of the landfill (approximately 3 m) effectively minimizes the depth of refuse through which water infiltrates. Leachate strength in landfills is due to the leaching of organic matter and inorganic ions and the dissolution of carbonate material from the waste and cover material (hence the name leachate). The thin waste layer at Centennial Park minimizes the leaching process that occurs during recharge or infiltration. Effectively, the waste has

been placed at a low density, with correspondingly low leachate strength.

2) From the physical hydrology investigations discussed previously, we know that infiltrating water travels downward into the landfill (indicated by gradient data) and horizontally towards the Bay of Quinte, perhaps at a rate of 7 to 110 m/year (Section 4.1). This cycle may have effectively flushed leached constituents into the Bay of Quinte with progressively lower strength leachate being produced in time. If this decline in leachate strength is occurring, the flushing would result in progressively lower concentrations of the leachate in each well (beginning with the upgradient wells) as the constituents are flushed downgradient.

Different leachate parameters are flushed downgradient or transported at varying rates. The retardation of some parameters relative to others is caused by chemical and biochemical processes (i.e. adsorption-desorption reactions, acid-base reactions, solution-precipitation reactions, oxidation-reduction reactions, ion pairing or complexation etc). Generally, chloride migration is one of the fastest with unretarded transport, while iron and other metals do not migrate as quickly. Thus the presence of high chloride and low iron at a sampling point may indicate that severe contamination has not yet reached that point, while the presence of iron and other metals indicate further plume migration is occurring. Parameters which are retarded are usually measurable at a monitoring point for longer periods of time. Organics generally have slower migration rates than most inorganics. Plume migration information is useful in this case to predict the potential impact of the landfill on the Bay of Quinte as the leachate is flushed into the surface water.

The downgradient piezometers, P1 and P2, have higher concentrations of conductivity, chloride, phenols, alkalinity, magnesium and potassium relative to P3 and P4. It appears that the most mobile constituents have migrated past the upgradient piezometers. No clear trend between up- and downgradient piezometers is visible in the other parameters. The lack of a trend in the remaining constituents may be due to local variations in the waste.

No obvious trend in different levels of the multilevels was observed. This may be due to the close proximity of the two sampling points: the distance between the two may be too small to recognize the process described above.

5.2.2 Surface Water

The concentrations measured in the surface water samples were all within the MOE drinking water objectives except for phenols. Phenol concentrations, measured at 4.4 ppb and 4.2 ppb, are on the same order of magnitude as those measured in the landfill leachate (<1.0 to 10.4 ppb). It is unlikely that the levels found in the surface water can be attributed entirely to the landfill leachate, since considerably lower levels of other leachate constituents (for example, sodium potassium, magnesium, calcium, alkalinity, manganese and iron) are found in surface water indicating significant dilution of the leachate has occurred.

Decreases in the conductivity, iron and magnesium concentration since the MOE sampling of the Bay of Quinte in 1981 (Appendix B) suggest the water quality has improved, although the sporadic sampling events provide limited information.

While leachate is almost certainly infiltrating into the Bay, the discharge is so low that even at the immediate shoreline dilution has brought the concentrations of inorganic parameters well within the drinking water objectives. An evaluation of Table 5 shows that most constituents are diluted by a factor of an order of magnitude or more.

5.3 Organic Chemistry

5.3.1 Groundwater

Volatile Priority Pollutants

Measurable levels of nine volatile organic compounds were found in the landfill leachate samples. It should be noted that drinking water objectives have not been set for most organic compounds.

Benzene, toluene and xylene (BTX) are common constituents of petroleum (both naturally occurring and man-made). Levels found in the investigation are relatively low (<10 ppb) and may be attributed to either background or landfill sources. Naturally occurring BTX compounds were found in bedrock in the Belleville area at concentrations as high as 100 ppb (pers. comm. Mr. John Tooley, Abatement Section, MOE, Belleville). The Verulam Formation, an interbedded petroliferous limestone and shale, underlies both the Belleville site and the Centennial Park Landfill site, suggesting the BTX concentrations measured in the present site may well be from a natural source.

Halogenated compounds, such as chlorobenzene and 1,3 -dichlorobenzene, are unlikely to occur in the background

groundwater chemistry. Elevated chloride associated with landfill waste levels in P1-1 (970 mg/l), where highest chlorobenzene levels were found, further suggest that the chlorobenzenes are related to landfill material.

Relatively high levels of "Other Aromatic Compounds" or aromatic compounds which are not included as USEPA priority pollutants, were found in P1-1 (170 ppb). These could include a variety of compounds, likely compounds with low carbon numbers since they have volatilized (ie. trimethylbenzene).

Extractable Priority Pollutants

Seven types of extractable organic compounds were found in the samples submitted for analysis (Table 6).

Phthalates are ubiquitous in the environment at low levels and can also be present in sampling and/or laboratory equipment. They are commonly detected in routine extractable organic analyses.

The presence of 1,4-Dichlorobenzene is probably related to the halogenated compounds found in the volatile organic analyses. As discussed in Section 5.3.1, their origin is likely landfill related.

Fluorene and naphthalene are polycyclic aromatic hydrocarbons. They are present in low levels which may be associated with natural sources but are more likely related to landfill waste, most likely from wood preservative waste emplaced by Domtar or as products of degradation of other hydrocarbons.

Phenol was reported only in P1-1 at a level of 1.6 ppb, which is lower than that found in the index parameter analyzed by a colourmetric method (the 4-aminoantipyrene method). This is because the USEPA scans include only specific phenol compounds whereas the colourmetric method includes both phenol and phenolic-like compounds.

Both industrial and domestic waste may be responsible for the organic pollutants discussed above. While it is difficult and unrewarding to determine exact sources of the organic parameters, industries in the Trenton area, including wood preservation, electrical motor manufacture, electric wire manufacture, plastics manufacture and steel products may have contributed to the organic concentrations measured. The levels detected are relatively low concentrations and do not suggest substantial off-site migration with associated measurable levels of impact at any point of impingement.

5.3.2 Surface Water

Organic analyses were not done on the Bay of Quinte since only low levels (<10 ppb) were found in the groundwater. The inorganic analyses conducted on both groundwater and surface water indicated that all constituents carried in the groundwater are significantly diluted in the Bay relative to the leachate (Section 5.2.2). It was concluded that significant organic contamination of the Bay of Quinte by landfill leachate is unlikely.

5.4 Methane Gas Monitoring

Methane gas is presently being generated at Centennial Park and was detected in all of the gas probes installed. The methane gas may be from the landfill (including sawdust deposited in the northwest corner of the landfill) or from the marsh that existed previously in the area. Total combustible vapour concentrations measured in 2 out of 4 gas probes installed directly into the waste material were recorded as greater than 1% by volume or greater than 20% of the lower explosive limit. Methane wells installed adjacent to residential areas (M1,M2,M3,M4) have levels ranging from 0.1 to >1% by volume. These values represent a measure of total combustible gases including factors of interference such as H_2S and CO_2.

Levels of 0.5 and 0.15% by volume measured in M1 and M2, respectively, indicate that landfill-generated gases are travelling through the native soil some 40 meters away from the edge of the landfill. ?

Four homes judged to be the most susceptible to the accumulation of potentially combustible gases from the landfill were monitored for the combustible gas on September 19, 1988. Three of the four homes did not have basements, where methane accumulation usually occurs. No combustible gases were detected in any of the homes or in the Bay Street storm sewer.

It appears that the combustible gases generated in the landfill and shown to be migrating toward the residential areas to the north and east are being dissipated into the atmosphere or possibly being intercepted and vented by service trenches in the right of way. The landfill is relatively old and it would be reasonable to assume that gas production has peaked and is declining at the site. The elevated levels of combustible gases found on the landfill side of the street would, however, suggest that development in these areas should be preceded by site specific evaluations of soil gas conditions.

Gas migration characteristics vary seasonally with water table and frost level fluctuation. The worst case

situation envisaged for the site include a short seasonal surge in gas migration induced by a confining layer of frost or possibly a slug of infiltrating groundwater. To completely eliminate gas hazards as a potential problem in adjacent areas a re-sampling of gas monitors after freeze-up is suggested.

Elevated levels recorded in the concession stand in May, 1988, indicated that although the stand was built on native material (originally an island in the bay) combustible gases had migrated into the building during the winter months. City staff and lessees should be made aware of the situation and proper venting of the building, especially during the off-season and periods where the facility is closed up, should be investigated.

6.0 CONCLUSIONS

With respect to the objectives of the study, the following conclusions are drawn from the hydrogeological study of the closed Centennial Park Landfill site in Trenton, Ontario.

1. The leachate characteristics are typical of low strength leachate. Measurable levels of fourteen different organic compounds were found in the leachate at relatively low levels (<10 ppb). While some of the compounds can be attributed to natural and laboratory sources, landfill related organic contamination of groundwater has occurred. Unidentified industrial waste was almost certainly disposed of at the site.

2. Although hydrogeologic investigations indicated that leachate was being flushed into the Bay of Quinte, no impact on the surface water was observed in the field or laboratory geochemical analyses of surface water.

   Dilution of the low strength leachate is reducing measurable constituents to within the drinking water objectives. This was demonstrated through the use of conservative inorganic leachate constituents and inferred for the more heavily retarded and less concentrated organic compounds.

3. The Centennial Park Landfill is actively producing methane. Combustible gas concentrations greater than 1% by volume were measured in three of the eight installations during drilling or monitoring. In addition, levels of combustible gas up to 0.4% by volume were measured some 40 metres away from the edge of the landfill. Combustible gases were not detected off-site in houses monitored on Bay Street or in storm drains. Given the limitations of 'one-time' sampling

events, the potential for migration of the gas into enclosed areas still exists especially in areas south of Bay Street on properties directly adjacent to the landfill.

4. The site's present physical condition is good. The parkland is well used by the public and no indications of the former site use are evident.

7.0 RECOMMENDATIONS

The following recommendation is made for site improvement with respect to site monitoring. No remedial action is recommended at the present time.

1. The possibility of methane gas migration and accumulation in enclosed spaces on and adjacent to the landfill site still exists. It is recommended that the gas probes installed along Bay Street and a number of residential basements and storm sewers be monitored to observe seasonal and temporal changes in the gas concentration. Some of the sampling events should occur in the late winter when frost has been present for several months. This will be the period of maximum gas build-up.

   If levels higher than those found in the present investigations are found, then additional house and storm sewer monitoring should be undertaken. If new structures are constructed on or adjacent to the site their design should encorporate adequate monitoring opportunities.

   Caution should be exercised in the opening of the concession stand and the amphitheatre after they have been closed up for any length of time. Measurements in the present study have indicated that combustible gas accumulation can occur.

   A long-term solution would include some form of building ventilation system that would operate even when the buildings are closed.

Respectfully Submitted,

Roger M. Woeller, M.Sc.
Hydrogeologist

Cathy Ryan, M.Sc.
Hydrogeologist

8.0 REFERENCES

Freeze, R.A. and Cherry J.A. 1979. **Groundwater.** Prentice-Hall Inc., New Jersey.

Lee, D.R. and Cherry, J.A. 1978. **A field exercise on groundwater flow using seepage meters and mini-piezometers.** Journal of Geological Education, 27, pp.6-10.

Water and Earth Science Associates, in association with MacLaren Engineers. January, 1988. **Gloucester Landfill Waste Site Clean Up, Phase I, Stage II - Sampling, Analysis and Plume Definition Program.** Prepared for Transport Canada Airports Authority Group.

APPENDIX A:

INVENTORY OF INDUSTRIES THAT MAY MAY HAVE LANDFILLED AT CENTENNIAL PARK LANDFILL

(information supplied by the
City of Trenton)

INDUSTRY	ESTABLISHED	PRODUCTS
ARC INDUSTRIES	1969	Contract cleaning, subcontract work assembling, packaging, furniture refinishing. Woodworking, Yard Maintenance, Snow Removal
CAMP INTERNATIONAL LIMITED	1936	Surgical support and appliances, mastectomy products
CARRYING INDUSTRIES LIMITED	1970	Custom manufacturing of leather, webbing and canvas products
CRANE CANADA INC.	1969	Vitreous china, lavatories, water closets, plumbing fixtures, etc.
DCA CANADA INC.	1935	Dry mix preparation: donuts, muffins, cake mixes, etc. Equipment for donut shops
DOMTAR CHEMICALS GROUP	1920s	Treated utility poles, piling, railway ties, and construction lumber
DOMTAR PACKAGING	1927	Manufacture of corrugating medium pulp
EMHART CANADA LTD.	1901	Architectural hardware
GENERAL ELECTRIC OF CANADA LIMITED	1966	Electric motors for washing machines, dryers and sump pumps
MOORE BUSINESS FORMS AND SYSTEMS DIVISION	1969	Continuous business forms, pressure sensitive labels and direct mail products

MORTON-PARKER LIMITED	1969	Silver plated holloware for retail and institutional
market.		
MURATA ERIE NORTH AMERICA, LTD.	1934	Electronic components
PYROTENAX OF CANADA LIMITED	1953	Mineral insulated cable and accessories for electric wiring, electric heating,instrumentation, temperature measurement and associated control equipment.
QUAKER OATS COMPANY OF CANADA LIMITED	1952	Cat and dog foods.
RIVERSIDE CHEESE & BUTTER	1930	Manufacture of cheddar, specialty cheese and butter.
TRENTON COLD STORAGE LIMITED	1902	Refrigerated warehousing and distribution.
TRENTONIAN & TRI COUNTY NEWS	1930´s	Newspapers and rotary printing.
VAGDEN MILLS LIMITED	1958	Socks for Men.
BATA FOOTWEAR BATAWA, ONTARIO	1939	Footwear.
INVAR MANUFACTURING,	1939	Precision machining and fabrication of a wide array of complex components, hydraulic cylinders, assemblies and systems for the Defense, Commercial, Aircraft/Aerospace, Transportation and Nuclear Energy Markets.
MILLER SAFETY LIMITED	1961	Fall Arresting Products.
PAPERBOARD INDUSTRIES	1882	300 tonnes per day of boxboard, containerboard and specialty papers.
QUINTE MACHINE & STEEL LTD.	1950	Custom fabricating - steel, aluminum and stainless, machining, structural steel fabrication and erectors, millwrighting, boiler repairs.

APPENDIX B:

RESULTS FROM M.O.E. SAMPLING
OF BAY OF QUINTE, 1979

RESULTS FROM M.O.E. SAMPLING OF BAY OF QUINTE
NEAR CENTENNIAL PARK LANDFILL

SAMPLE LOCATIONS:

MOE LAB NO.	LOCATION
KW 43-85	700 feet west of new Bay Street storm sewer
KW 43-86	350 feet west of new Bay Street storm sewer
KW 43-87	500 feet east of W.P.C.P.
KW 43-88	300 feet east of W.P.C.P.

MOE LAB NO.	HARDNESS	ALK	PH	COND (Mmhos/cm)	BOD_5	Fe	Cl	NH_3	TKN	NO_2	NO_3	Ca	Mg	Na	SO_4	DATE SAMPLED
KW 43-85	112	102	8.0	245	1.0	0.05	7.5	0.11	0.78	0.020	0.18	39	8.3	5.5	7.7	09/81
KW 43-86	130	102	7.9	245	1.3	0.15	8.0	0.12	0.82	0.024	0.18	38	8.7	5.7	8.8	09/81
KW 43-87	132	109	7.7	310	1.1	0.20	16.5	0.07	0.92	0.31	1.33	46	4.3	11	12	09/81
KW 43-88	128	107	7.7	300	1.0	0.25	15.5	0.06	0.86	0.15	1.55	43	4.8	10	11	09/81

APPENDIX C:

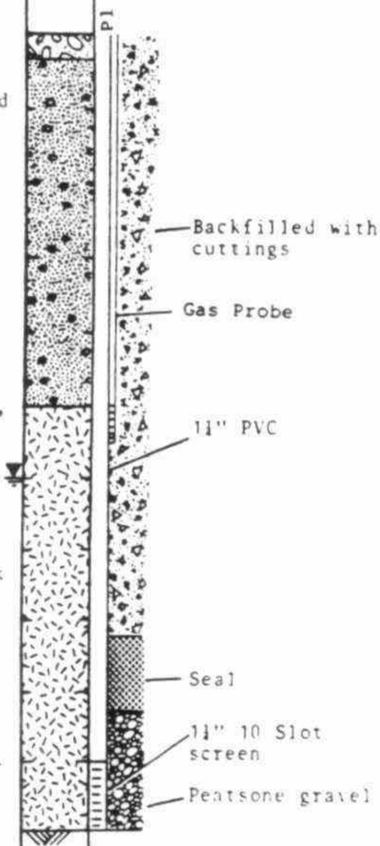
RECORDS OF TEST HOLES

RECORD OF TEST HOLE

DESIGNATION	P1
COMPLETION DATE	April 25/88
PROJECT	CENTENNIAL PARK LANDFILL, TRENTON
PROJECT NO.	T1690
DRILLING METHODS	HOLLOW STEM AUGER
SUPERVISOR	I. MACDONALD
DRILLING CONTRACTOR	ALL TERRAIN DRILLING LTD.

DEPTH FT	DEPTH M	ELEVATION METRES	STRATIGRAPHY & HYDROSTRATIGRAPHY
0	0	77.88	Cover Material - building materials asphalt, cement
			Cover Material - coarse grained sand pebbles
2			Coarse Grained Grey Sand with 30% rounded pebble gravel, pieces of cardboard
5		76.36	Landfill - black rubber base, paper, plastic
7			Landfill - materials mixed with dark grey to black sand, no smell.
10	3	74.23	Landfill - mixed with limestone bed-rock chips
11		74.53	

LOG / INSTRUMENTATION



SAMPLING

TYPE	INTERVAL	N VALUE
		50
		100
		812
		4
		2
		5
		7
		2
		2
		3
		40
		3
		5
		10
		11
		5
		10
		18
		24

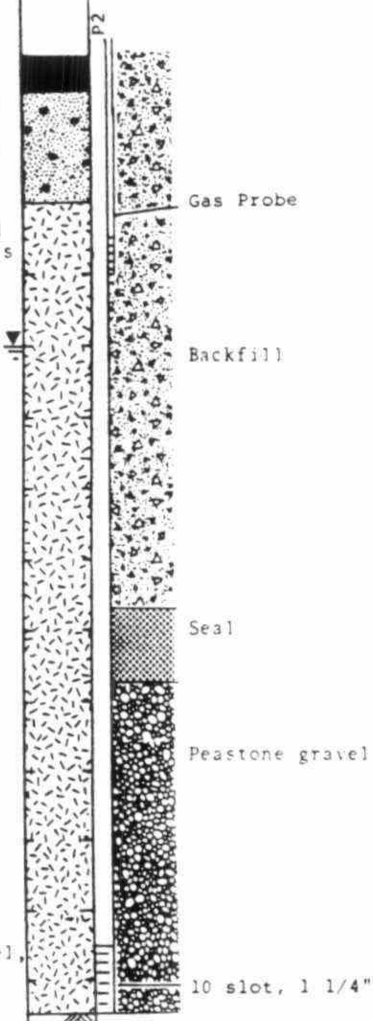
WATER AND EARTH SCIENCE ASSOCIATES LTD.

	RECORD OF TEST HOLE	DESIGNATION P2	COMPLETION DATE April 25/88

PROJECT CENTENNIAL PARK LANDFILL, TRENTON
PROJECT NO. T1690

DRILLING METHODS HOLLOW STEM AUGER
SUPERVISOR I. MACDONALD
DRILLING CONTRACTOR ALL TERRAIN DRILLING LTD.

DEPTH FT	DEPTH M	ELEVATION METRES	STRATIGRAPHY & HYDROSTRATIGRAPHY	SAMPLING TYPE	SAMPLING N VALUE
0	0	76.50	Black Organic Rich Topsoil - coarse grained, loose with grass roots, mixed with 20% grey clay with high plasticity	SS	5 5 5 [illegible] 4 [illegible] [illegible] 8
1			Medium Grained Brown Sand - with 10% brown clay and 10% fine pebble gravel		
2			Landfill - medium grained brown sand with granitic and limestone pebbles and gravel, wood fibres	SS	
3	1	75.59			
4					
5				SS	[illegible] 10 9 11
6					
7	2				
8			Medium to Coarse Grained Sand - 10% pebbles and cobbles, black water (leachate) present, no smell.	SS	4 4 4 4
9					
10	3			SS	5 8 12 100+
11					
12					
13	4	72.69	Light Grey Fine Sand or Clay - gravel, wood fibres, water still black		12 100+
		72.39			
14					
15					
16					
17					
18					



WATER AND EARTH SCIENCE ASSOCIATES LTD.

RECORD OF TEST HOLE

DESIGNATION: P3

COMPLETION DATE: April 25/88

PROJECT: CENTENNIAL PARK LANDFILL, TRENTON

PROJECT NO.: T1690

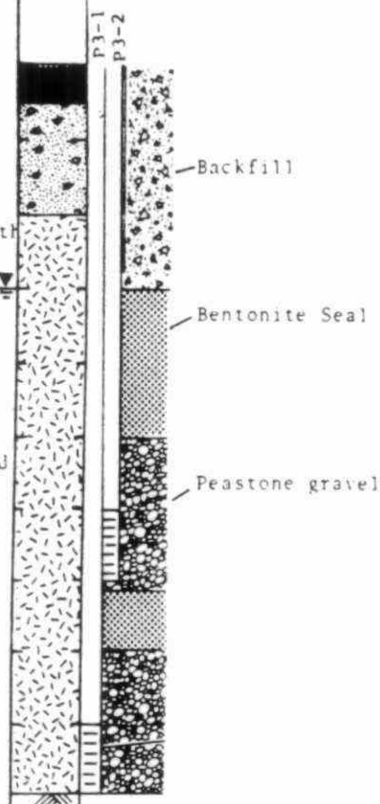
DRILLING METHODS: HOLLOW STEM AUGER

SUPERVISOR: I. MACDONALD

DRILLING CONTRACTOR: ALL TERRAIN DRILLING LTD.

DEPTH FT	DEPTH M	ELEVATION METRES	STRATIGRAPHY & HYDROSTRATIGRAPHY	SAMPLING TYPE	N VALUE
0	0	76.75	Topsoil - medium grained dark brown sand with high humus, roots near the surface		
1			Sand - medium grained, brown sand with approximately 10% coarse angular gravel	SS	3 4 5 13
2		76.14	Medium Grained Dark Brown Sand - with 40% broken rock fragments, fill materials, some landfill material (paper, tin cans)		
3	1			SS	
4					
5			- 5% if sample volume filled in split spoon - dark grey fine grained sand with 10% clay	SS	4 2 2 2
6					
7	2				
8			Fine Grained Sand or Clay - light grey, 10% rounded to subangular and 10% angular broken rock fragments - dark brown to black water - no smell	SS	8 22 82 200+
9					
10	3	75.70			
11					
12					
13	4				
14					
15					
16					
17					
18					

LOG / INSTRUMENTATION



WATER AND EARTH SCIENCE ASSOCIATES LTD.

RECORD OF TEST HOLE

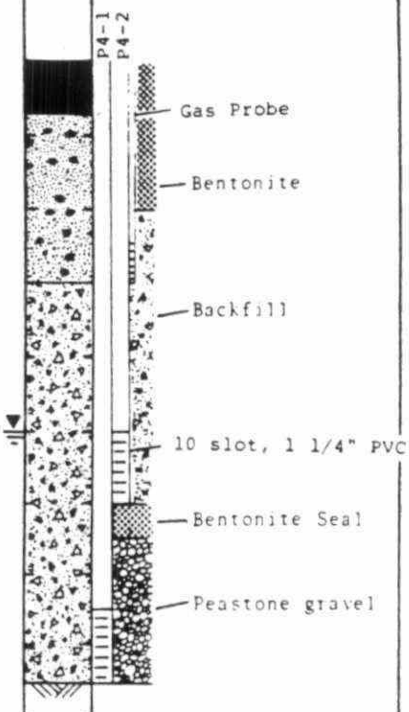
DESIGNATION	COMPLETION DATE
P4	April 25/88

PROJECT CENTENNIAL PARK LANDFILL, TRENTON
PROJECT NO. T1690

DRILLING METHODS HOLLOW STEM AUGER
SUPERVISOR I. MACDONALD
DRILLING CONTRACTOR ALL TERRAIN DRILLING LTD.

DEPTH FT	DEPTH M	ELEVATION METRES	STRATIGRAPHY & HYDROSTRATIGRAPHY	SAMPLING TYPE	N VALUE
0	0	77.31	Black Organic Rich Topsoil - coarse grained, loose with grass roots.		
1			Dark Brown Silty Sand - some grey clay lenses with high plasticity approximately 10% angular pebbles 2 cm Ø.	SS	12 8 5 9 8
2			Dark Brown Silty Sand		
3	1	76.40	Grey Brown Clay - high plasticity, angular, rounded gravel up to 6 cm Ø (15%)	SS	4 9 14 8
4					
5			Medium Grained Sand - grey, clean, mixed with dark brown to black wood chips, rounded pebbles to 4 cm Ø.	SS	3 3 3 3
6			Clay - grey brown, high plasticity		
7	2		Wood Chips - mixed with brown sand		
		75.02	Clay - grey, plastic, 10% fine grained sand, landfill material (plastic, tin), angular gravel to 5 cm Ø.		27 100
8		74.72	Weathered Bedrock Chips- mixed with grey brown clay		
9					
10	3				
11					
12					
13	4				
14					
15					
16					
17					
18					

LOG / INSTRUMENTATION



WATER AND EARTH SCIENCE ASSOCIATES LTD.

RECORD OF TEST HOLE

DESIGNATION	COMPLETION DATE
M1	April 25/88

PROJECT: CENTENNIAL PARK LANDFILL, TRENTON

PROJECT NO.: T1690

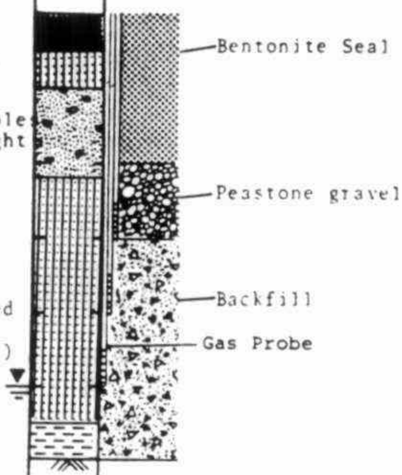
DRILLING METHODS: HOLLOW STEM AUGER

SUPERVISOR: I. MACDONALD

DRILLING CONTRACTOR: ALL TERRAIN DRILLING LTD.

DEPTH FT	DEPTH M	ELEVATION METRES	STRATIGRAPHY & HYDROSTRATIGRAPHY	SAMPLING TYPE
0	0	78.13	Dark Brown Organic Soil - roots	
1			Brown Silty Sand - medium grained, rounded pebbles, approximately 1 cm Ø.	SS
2			Gravel and Clay - 50% angular pebbles Ø = 2.5 cm, dry, sandy clay, light to medium brown, hard, low plasticity.	
3	1	77.22	Silty Sand - loose, medium brown, few founded pebbles, Ø 1 cm.	SS
4		76.91	- Approximately 30% gravel observed in auger cuttings, garbage (plastic bags, tape, baby diaper) also observed.	
5		76.61	Clay - dark brown to black, high plasticity, wet	
6		76.30		
7	2			
8				
9				
10	3			
11				
12				
13	4			
14				
15				
16				
17				
18				

LOG / INSTRUMENTATION



SAMPLING: TYPE | INTERVAL | N VALUE

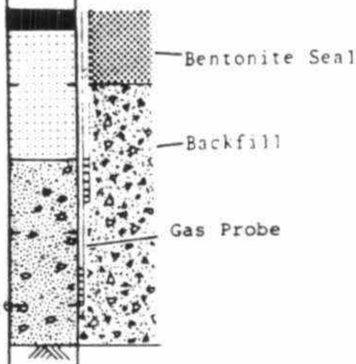
WATER AND EARTH SCIENCE ASSOCIATES LTD.

RECORD OF TEST HOLE

DESIGNATION	M2
COMPLETION DATE	April 26/88
PROJECT	CENTENNIAL PARK LANDFILL, TRENTON
PROJECT NO.	T1690
DRILLING METHODS	HOLLOW STEM AUGER
SUPERVISOR	I. MACDONALD
DRILLING CONTRACTOR	ALL TERRAIN DRILLING LTD.

DEPTH FT	DEPTH M	ELEVATION METRES	STRATIGRAPHY & HYDROSTRATIGRAPHY	SAMPLING TYPE	N VALUE
0	0	77.19	Topsoil - light brown, fine grained silty sand, roots		
1			Sand - dark brown, medium grained 20% angular pebbles and broken rock fragments	SS	13, 26, 26, 13
2		76.43	- as above with 40% rock fragments		
3	1			SS	6, 12, 100+
4		75.97	Bedrock Chips - light grey, limestone fresh, angular		
		75.82			
5					
6					
7	2				
8					
9					
10	3				
11					
12					
13	4				
14					
15					
16					
17					
18					

LOG / INSTRUMENTATION



WATER AND EARTH SCIENCE ASSOCIATES LTD.

RECORD OF TEST HOLE

DESIGNATION: M3

COMPLETION DATE: April 26/88

PROJECT: CENTENNIAL PARK LANDFILL, TRENTON

PROJECT NO.: T1690

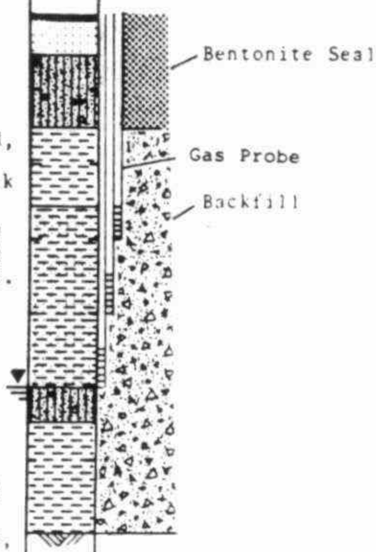
DRILLING METHODS: HOLLOW STEM AUGER

SUPERVISOR: I. MACDONALD

DRILLING CONTRACTOR: ALL TERRAIN DRILLING LTD.

DEPTH FT	DEPTH M	ELEVATION METRES	STRATIGRAPHY & HYDROSTRATIGRAPHY	SAMPLING TYPE	N VALUE
0	0	77.66	Sand - dark brown, medium grained, humus-rich		
			Silty Sand - dark brown, medium grained sand with silt	SS	6, 16, 32, 40
1					
2			Clay - light grey, highly compacted, dry and stiff, approximately 10% broken granitic and limestone rock fragments		
3	1	75.53	Clay - black-grey, 30% fine grained sand, low plasticity, 10% rounded pebbles (Ø 1 cm), wood fragments.	SS	7, 5, 4, 4
4		75.83			
5		76.14	Silty Sand - dark brown, medium grained sand, rounded pebbles, Ø 1 cm.		6, 12, 45, 60
6	2		Clay - brown grey, high plasticity, light brown sandy lenses (10%) - 20% angular pebbles, Ø 2 cm.		
7		77.53	Bedrock Chips - 80% angular pebbles, light grey, limestone, 20% grey clay		
8					
9					
10	3				
11					
12					
13	4				
14					
15					
16					
17					
18					

LOG / INSTRUMENTATION



WATER AND EARTH SCIENCE ASSOCIATES LTD.

RECORD OF TEST HOLE

DESIGNATION	COMPLETION DATE
M4	April 26/88

PROJECT CENTENNIAL PARK LANDFILL, TRENTON

PROJECT NO. T1690

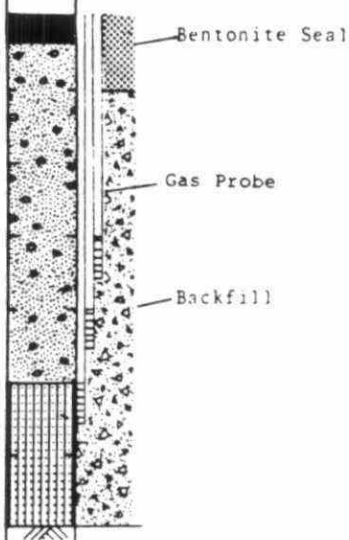
DRILLING METHODS HOLLOW STEM AUGER

SUPERVISOR I. MACDONALD

DRILLING CONTRACTOR ALL TERRAIN DRILLING LTD.

DEPTH FT	DEPTH M	ELEVATION METRES	STRATIGRAPHY & HYDROSTRATIGRAPHY
0	0	77.66	Topsoil - dark brown, medium grained sand with humus and roots
			Sand - light brown, medium grained, 20% rounded cobbles and gravel (limestone and granitic)
3	1	76.59	
		76.29	
		75.98	Sandy Silt - light grey, fine grained sand to silt with black, organic rich lenses, high plasticity - 30% broken rock chips (angular, light grey, limestone).
7	2	75.52	

Depth scale: 0 to 18 FT; 0 to 4 M.



SAMPLING TYPE	N VALUE
SS	2, 5, 9, 11
SS	10, 9, 5, 4
SS	3, 5, 12, 27

WATER AND EARTH SCIENCE ASSOCIATES LTD.

APPENDIX D:

INORGANIC WATER CHEMISTRY RESULTS

DEPARTMENT OF CHEMISTRY

Queen's University
Kingston, Canada
K7L 3N6

May 19, 1988

Results of Analyses of Water Samples for WESA

Submitted 11 May 1988 - Project 1690 - Cathy Ryan

Trenton	IRON (ppm)	MANGANESE (ppm)	COD (ppm)	ALKALINITY (ppm)	PHENOLS (ppb)	CHLORIDE (ppm)	NITRATE(N) (ppm)	SULPHATE (ppm)
P1-1	52.5	0.64	82	1290	10.8	970	<10	<2
P2-1	11.6	1.79	65	1010	6.0	195	<1	27
P3-1	9.0	1.01	77	945	<1.0	47	<1	4
P3-2	1.8	0.72	56	740	1.4	55	<1	61
P4-1	30.2	1.62	74	895	4.0	57	<1	<2
P4-2	4.9	1.65	320	920	6.6	185	<1	42
Picton								
P1-1	<0.10	0.09	<3	318	<1.0	81	<1	29
P1-2	11.1	2.85	154	1038	143	131	<1	28
P2-1	0.60	0.09	<3	296	<1.0	718	<1	9
P2-2	61.0	0.54	220	-	-	29	5.0	309
P3-1	<0.10	0.08	<3	285	<1.0	140	<1	9
P3-2	<0.10	1.40	6	483	<1.0	125	<1	25
P3-3	<0.10	<0.05	25	10	<1.0	<1	<1	<2
P3-4	0.15	0.19	12	251	<1.0	138	<1	10
P-4	11.2	0.08	27	291	3.0	142	<1	<2
			BOD					
Trenton								
SW1	<0.10	<0.05	<5	100	4.4	13	<1	12
SW2	<0.10	<0.05	<5	105	4.2	24	<1	16
Picton								
SW1	<0.10	0.08	<5	209	<1.0	56	5.0	59
SW2	<0.10	0.23	<5	230	<1.0	57.3	<1	5
SM1	<0.10	0.05	<5	502	-	166	<1	<2

	AMMONIUM as N (ppm)	CALCIUM (ppm)	MAGNESIUM (ppm)	POTASSIUM (ppm)	SODIUM (ppm)
Trenton					
P1-1	47.	310	42	32	470
P2-1	23.	324	43	10.9	106
P3-1	36.	270	43	36	78
P3-2	35.	174	26	27	160
P4-1	19	236	24	30	63
P4-2	33	240	26	28	145
Picton					
P1-1	<0.10	94	23	6.3	56
P1-2	19.	282	37	30	90
P2-1	0.47	136	46	11.5	460
P2-2	<0.10	-	-	-	-
P3-1	0.12	89	35	3.8	45
P3-2	0.23	170	40	2.7	34
P3-3	<0.10	<1.0	<1.0	0.7	2.1
P3-4	<0.10	80	38	3.9	~~[illegible]~~ 46
P-4	8.5	83	13	10.8	68
Trenton					
SW1	<0.10	46	3.6	1.2	5.4
SW2	<0.10	48	3.9	1.5	9.5
Picton					
SW1	3.3	74	7.9	7.1	39
SW2	<0.10	80	7.5	2.0	13
SM1	14	143	41.	2.8	37

John S Pick...

APPENDIX E:

ORGANIC CHEMISTRY RESULTS

(EPA 624 & 625 SCANS)

NOVALAB LTÉE LTD
9420 CÔTE DE LIESSE, LACHINE, QUÉ. H8T 1A1
TÉL: (514) 636-6218, 631-1838
TÉLEX: 05-822787 • (LYNJON)
FAX: (514) 631-9814

TO: Water & Earth Science Assoc.
Box 430
Carp, Ontario
KOA 1LO

DATE: May 31, 1988

CLIENT ORDER #:

Attention: Ms. Cathy Ryan

REPORT #: NL-3650

RE: Analysis of Water Samples for Priority Pollutants

Ms. Ryan,

Five (5) water samples, received May 13, 1988, were analysed for volatile and extractable priority pollutants by gc/ms. Results and detection limits are shown in the attached Tables.

Chromatograms will be kept on file. Results are not corrected for recovery.

Sincerely,

NOVALAB LIMITED

B.E. Crowley, B.Sc.

Approved by J.D. Fenwick, Ph.D., P.Chem.

CHIMISTE
John D. Fenwick
74-024
QUÉBEC

BEC/hl
encl.

All reports are the confidential property of clients. Publication of statements, conclusions or extracts regarding our reports is not permitted without our written approval. Any liability attached thereto is limited to the fee charged. Unless otherwise arranged samples will be discarded 90 days after receipt.

CONCENTRATION OF VOLATILE PRIORITY POLLUTANTS IN WATER
ug/L

COMPOUND	T16RO P1-1	T16RL P2-1	T16RL P3-1	F16RO P1-2	F16RL P2-2	BLANK	MDL
BENZENE	5.5	2.0	1.4	4.5			1
BROMODICHLOROMETHANE	-	-	-	-	-	-	1
BROMOFORM	-	-	-	-	-	-	1
BROMOMETHANE	-	-	-	-	-	-	10
CARBON TETRACHLORIDE	-	-	-	-	-	-	1
CHLOROBENZENE	22	2.4	4.2	1	-	-	1
CHLOROETHANE	-	-	-	-	-	-	10
2-CHLOROETHYL VINYL ETHER	-	-	-	-	-	-	10
CHLOROFORM	-	-	-	9.7	-	-	1
CHLOROMETHANE	-	-	-	-	-	-	50
DIBROMOCHLOROMETHANE	-	-	-	-	-	-	1
1,2-DICHLOROBENZENE	-	-	-	-	-	-	1
1,3-DICHLOROBENZENE	7.8	1.6	2.2	-	-	-	1
1,4-DICHLOROBENZENE	-	-	-	-	-	-	1
1,1-DICHLOROETHYLENE	-	-	-	2.8	-	-	1
1,1-DICHLOROETHANE	-	-	-	7.9	-	-	1
1,2-DICHLOROETHANE	-	-	-	-	-	-	1
TRANS-1,2-DICHLOROETHYLENE	-	-	-	-	-	-	1
DICHLOROMETHANE	-	-	-	-	-	-	10
1,2-DICHLOROPROPANE	-	-	-	-	-	-	1
CIS-1,3-DICHLOROPROPENE	-	-	-	-	-	-	1
TRANS-1,3-DICHLOROPROPENE	-	-	-	-	-	-	1
ETHYLBENZENE	1.6	1.4	2	12	-	-	1
A-METHYLSTYRENE	-	-	-	-	-	-	1
METHYLSTYRENE ISOMERS	-	-	-	-	-	-	1
MESITYLENE	-	-	-	-	-	-	1
1,1,2,2-TETRACHLOROETHANE	-	-	-	-	-	-	1
TETRACHLOROETHYLENE	-	-	-	1	-	-	1
TOLUENE	2.5	8	10	5.2	-	-	1
1,1,1-TRICHLOROETHANE	-	-	-	-	-	-	1
1,1,2-TRICHLOROETHANE	-	-	-	-	-	-	1
TRICHLOROETHYLENE	-	-	-	-	-	-	1
TRICHLOROFLUOROMETHANE	-	-	-	54	-	-	1
M+P-XYLENE	6.6	5.4	8.4	77	-	-	1
O-XYLENE	2	2.4	1.6	7.3	-	-	1
VINYL CHLORIDE	-	-	-	-	-	-	10
OTHER AROMATIC COMPOUNDS	170	11	15	140	-	-	1

MDL = METHOD DETECTION LIMITS

OTHER AROMATIC COMPOUNDS = Total concentration of tri- and tetramethylbenzenes using the response factor of mesitylene.

CONCENTRATION OF BASE/NEUTRAL PRIORITY POLLUTANTS IN WATER
ug/L

COMPOUND	T1690 P1-1	T1690 P2-1	T1690 P2-2	T1690 P1-2	T1690 P3-2	Trip blank	Lab blank	MDL
ACENAPHTHENE	-	-	-	-	-	-	-	1
ACENAPHTHYLENE	-	-	-	-	-	-	-	1
ANTHRACENE	-	-	-	-	-	-	-	1
BENZIDINE	-	-	-	-	-	-	-	20
BENZ(A)ANTHRACENE	-	-	-	-	-	-	-	1
BENZO(B)FLUORANTHENE	-	-	-	-	-	-	-	2
BENZO(K)FLUORANTHENE	-	-	-	-	-	-	-	2
BENZO(A)PYRENE	-	-	-	-	-	-	-	3
BENZO(GHI)PERYLENE	-	-	-	-	-	-	-	5
BENZYL BUTYL PHTHALATE	-	-	-	-	-	-	-	1
BIS(2-CHLOROETHYL)ETHER	-	-	-	-	-	-	-	1
BIS(2-CHLOROETHOXY)METHANE	-	-	-	-	-	-	-	1
BIS(2-ETHYLHEXYL)PHTHALATE	1.5	1.2	1.2	1.2	-	2.6	2.3	1
BIS(2-CHLOROISOPROPYL)ETHER	-	-	-	-	-	-	-	1
4-BROMOPHENYL PHENYL ETHER	-	-	-	-	-	-	-	1
2-CHLORONAPHTHALENE	-	-	-	-	-	-	-	1
4-CHLOROPHENYL PHENYL ETHER	-	-	-	-	-	-	-	1
CHRYSENE	-	-	-	-	-	-	-	1
DIBENZ(A,H)ANTHRACENE	-	-	-	-	-	-	-	5
DI-N-BUTYL PHTHALATE	6.7	3.5	3	3.9	4.5	3	2.5	1
1,3-DICHLOROBENZENE	-	-	-	-	-	-	-	1
1,4-DICHLOROBENZENE	3.7	-	1.4	1.2	-	-	-	1
1,2-DICHLOROBENZENE	-	-	-	-	-	-	-	1
3,3'-DICHLOROBENZIDINE	-	-	-	-	-	-	-	1
DIETHYL PHTHALATE	2.7	-	-	2	-	-	-	1
DIMETHYL PHTHALATE	-	-	-	-	-	-	-	1
2,4-DINITROTOLUENE	-	-	-	-	-	-	-	3
2,6-DINITROTOLUENE	-	-	-	-	-	-	-	3
1,2-DIPHENYLHYDRAZINE	-	-	-	-	-	-	-	1
DI-N-OCTYL PHTHALATE	-	-	-	-	-	-	-	1
FLUORANTHENE	-	-	-	-	-	-	-	1
FLUORENE	-	-	1.4	-	-	-	-	1
HEXACHLOROBENZENE	-	-	-	-	-	-	-	1
HEXACHLOROBUTADIENE	-	-	-	-	-	-	-	3
HEXACHLOROCYCLOPENTADIENE	-	-	-	-	-	-	-	5
HEXACHLOROETHANE	-	-	-	-	-	-	-	3
INDENO(1,2,3-CD)PYRENE	-	-	-	-	-	-	-	5
ISOPHORONE	-	-	-	-	-	-	-	1
NAPHTHALENE	24	1.6	-	3	-	-	-	1
NITROBENZENE	-	-	-	-	-	-	-	1
N-NITROSO-DI-N-PROPYLAMINE	-	-	-	-	-	-	-	1
N-NITROSODIPHENYLAMINE	-	-	-	-	-	-	-	1
PHENANTHRENE	-	-	-	-	-	-	-	1
PYRENE	-	-	-	-	-	-	-	1
1,2,4-TRICHLOROBENZENE	-	-	-	-	-	-	-	1

MDL = METHOD DETECTION LIMIT

Total concentration of benzo(b)- and benzo(k)fluoranthene is shown in the row for benzo(k)fluoranthene.

CONCENTRATION OF ACIDIC PRIORITY POLLUTANTS IN WATER
ug/L

COMPOUND	T1690 P1-1	T1690 P2-1	T1690 P2-2	T1690 P1-2	T1690 P3-2	Trip blank	Lab blank	MDL
PHENOL	1.6	-	-	73	-	-	-	[illegible]
2-CHLOROPHENOL	-	-	-	-	-	-	-	1
2,4-DIMETHYLPHENOL	-	-	-	-	-	-	-	6
4-CHLORO-3-METHYLPHENOL	-	-	-	-	-	-	-	1
2,4-DICHLOROPHENOL	-	-	-	-	-	-	-	[illegible]
2,4,6-TRICHLOROPHENOL	-	-	-	-	-	-	-	1
2-NITROPHENOL	-	-	-	-	-	-	-	2
2,4-DINITROPHENOL	-	-	-	-	-	-	-	6
2-METHYL-4,6-DINITROPHENOL	-	-	-	-	-	-	-	5
4-NITROPHENOL	-	-	-	-	-	-	-	5
PENTACHLOROPHENOL	-	-	-	-	-	-	-	3

MDL = METHOD DETECTION LIMIT
TR = TRACE

RECOVERY OF SURROGATE STANDARDS

COMPOUND	T1690 P1-1	T1690 P2-1	T1690 P2-2	T1690 P1-2	T1690 P3-2	Trip blank	Lab blank
D5-PHENOL	58.6	40.6	54.7	56.8	-	58.5	64.5
TRIFLUOROMETHYL-M-CRESOL	81.6	69.5	82.9	67.4	-	79.2	81
D5-NITROBENZENE	65.4	72.3	80.1	74.5	82.7	80.1	77.7
D10-ANTHRACENE	76	81.1	88.7	79	75.7	77.8	78.6
D12-PERYLENE	67.5	67.6	75.3	71.4	71.4	74.2	77.8

9420 CÔTE DE LIESSE, LACHINE, QUÉ. H8T 1A1

TÉL.: (514) 636-6218, 631-1838
TÉLEX: 05-822787 • (LYNJON)
FAX: (514) 631-9814

NOVALAB LTÉE LTD

TO: Water & Earth Science Assoc.
Box 430
Carp, Ontario
KOA 1LO

DATE: June 13, 1988

CLIENT ORDER #:

Attention: Ms. Cathy Ryan

REPORT #: NL-3680

RE: Analysis of Water Sample for VOC

Ms. Ryan,

Three (3) water samples were received June 7, 1988. One (1) of these samples and one (1) trip blank were analysed for volatile priority pollutants by purge and trap gc/ms. Results and detection limits are shown in the attached Table.

Chromatograms will be kept on file.

Sincerely,

NOVALAB LIMITED

B.E. Crowley, B.Sc.

Approved by J.D. Fenwick, Ph.D., P.Chem.

CHIMISTE
John D. Fenwick
74-024
QUÉBEC

BEC/hl
encl.

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CONCENTRATION OF VOLATILE PRIORITY POLLUTANTS IN WATER
ug/L

COMPOUND	T1690 -P2-1	TRIP BLANK	LAB BLANK	MDL
BENZENE	2.4	-	-	1
BROMODICHLOROMETHANE	-	-	-	1
BROMOFORM	-	-	-	2
BROMOMETHANE	-	-	-	10
CARBON TETRACHLORIDE	-	-	-	2
CHLOROBENZENE	1.1	-	-	1
CHLOROETHANE	-	-	-	10
2-CHLOROETHYL VINYL ETHER	-	-	-	10
CHLOROFORM	-	1.7	-	1
CHLOROMETHANE	-	-	-	50
DIBROMOCHLOROMETHANE	-	-	-	1
1,2-DICHLOROBENZENE	-	-	-	1
1,3-DICHLOROBENZENE	-	-	-	1
1,4-DICHLOROBENZENE	-	-	-	1
1,1-DICHLOROETHYLENE	-	-	-	1
1,1-DICHLOROETHANE	-	-	-	1
1,2-DICHLOROETHANE	-	-	-	2
TRANS-1,2-DICHLOROETHYLENE	-	-	-	1
DICHLOROMETHANE	-	-	-	10
1,2-DICHLOROPROPANE	-	-	-	1
CIS-1,3-DICHLOROPROPENE	-	-	-	1
TRANS-1,3-DICHLOROPROPENE	-	-	-	1
ETHYLBENZENE	1.7	-	-	1
A-METHYLSTYRENE	-	-	-	1
METHYLSTYRENE ISOMERS	1.9	-	-	1
MESITYLENE	-	-	-	1
1,1,2,2-TETRACHLOROETHANE	-	-	-	2
TETRACHLOROETHYLENE	-	-	-	1
TOLUENE	9.3	-	-	2
1,1,1-TRICHLOROETHANE	-	-	-	2
1,1,2-TRICHLOROETHANE	-	-	-	1
TRICHLOROETHYLENE	-	-	-	1
TRICHLOROFLUOROMETHANE	-	-	-	2
M+P-XYLENE	6.7	-	-	2
O-XYLENE	3.5	-	-	1
VINYL CHLORIDE	-	-	-	12
OTHER AROMATIC COMPOUNDS	7.7	-	-	1

MDL = METHOD DETECTION LIMITS

OTHER AROMATIC COMPOUNDS = Total concentration of tri- and tetramethylbenzenes using the response factor of mesitylene.

APPENDIX F:

DUPLICATE AND BLANK SAMPLES

Blanks and duplicates were employed in both organic and inorganic samples for quality assurance and control. A field blank and field duplicate were taken for inorganic analysis at the Trenton site. Since field sampling at both Trenton and Picton were done on the same field trip with the same sampling equipment, the blank and duplicate are considered to be entirely representative of the conditions at the Picton site.

INORGANIC ANALYSES

PARAMETER	DUPLICATE SAMPLE FROM PICTON SITE P3-1		FIELD BLANK
Fe (ppm)	<0.10	0.15	<0.10
Mn (ppm)	0.08	0.19	<0.05
COD (ppm)	<3	12	25
Alkalinity (ppm)	285	251	10
Phenols (ppb)	<1.0	<1.0	<1.0
Chloride (ppm)	140	138	<1
Nitrate-N (ppm)	<1	<1	<1
Sulphate (ppm)	9	10	<2
Ammonia-N (ppm)	0.12	<0.10	<0.10
Calcium (ppm)	89	80	<1.0
Magnesium (ppm)	35	38	<1.0
Potassium (ppm)	3.8	3.9	0.7
Sodium (ppm)	45	46	2.1
Calculated Hardness(ppm)	366	356	nil

ORGANIC ANALYSES

	DUPLICATE SAMPLES FROM TRENTON SITE P3-1 1	2	3	Trip Blank	Lab Blank
	May'88	May'88	June'88	June'88	
Benzene	3.4	2.7	2.4	-	-
Chlorobenzene	4.3	2.4	1.1	-	-
Chloroform	-	-	-	1.7	-
1,3-Dichlorobenzene	2.2	1.6	-	-	-
1,1-Dichloroethylene	-	-	-	-	-
1,1-Dichloroethane	-	-	-	-	-
Ethylbenzene	2	1.4	1.7	-	-
Methylstyrene Isomers	-	-	1.9	-	-
Tetrachlorethylene	-	-	-	-	-
Toluene	10	8	9.3	-	-
Trichlorofluoromethane	-	-	-	-	-
M+P-Xylene	8.4	5.4	6.7	-	-
O-Xylene	3.6	2.4	3.5	-	-
Other Aromatic Compounds	15	11	7.7	-	-
	BASE/NEUTRAL PRIORITY POLLUTANTS (ug/l)				
BIS(2-Ethylexyl)Phthalate	1.2	1.2	n/a	2.6	2.3
DI-N-Buthyl Phthalate	3.5	3	n/a	3	2.5
1,4-Dichlorobenzene	-	1.4	n/a	-	-
Diethyl Phthalate	-	-	n/a	-	-
Fluorene	-	1.4	n/a	-	-
Napthalene	1.6	-	n/a	-	-
	ACIDIC PRIORITY POLLUTANTS (ug/l)				
Phenol	-	-	n/a	-	-

NOTE: Only those compounds with detectable concentrations are include in the table. A complete listing of the EPA 625 and 624 compounds analyzed are included in Appendix E.

* Drinking Water Objective (WESA, 1988)
** Method Detection Limit

TD
795.7
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Hydrogeological assessment of
Centennial park waste disposal
site, Trenton (No. 360201)
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